Marine Protected Area Monitoring Technique: An Example from San Juan County

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Background

This project collected baseline data at four previously unsurveyed voluntary "no-take" bottomfish recovery zones (**BRZ**s) and their respective reference sites. When these sites are combined with the three pairs surveyed in 2001 (presented in the *2001 San Juan County Bottomfish Recovery Program Biological Assessment Final Report*), only Lawrence Point BRZ and its reference site are without baseline data. The four site pairs surveyed in 2002 included: Pile Point, Bare Island, Kellett Bluff and Gull Rock BRZs and their associated reference sites: Eagle Point, Skipjack Island, Open Bay, and Spieden Island.

Eight survey dives were undertaken at the four BRZs and their respective reference sites in August, and another eight surveys at the same sites were undertaken in September. These dives involved the primary observer from surveys completed in 2001 for counting and measuring eight target species of bottomfish, and, as in the 2001 surveys, a secondary observer for recording habitat data. A new component was included during 2002 surveys—two additional observers completed roving diver surveys using protocols developed by the Reef Environmental Education Foundation (**REEF**). These data can be used to compare biodiversity measures such as species richness for both fish and invertebrates beyond the eight target species.

The results for target species population densities and length frequency distributions showed few statistically significant differences between reserve and non-reserve site pairs. Positive reserve effects may take a decade or longer to become detectable given the population growth potential of these temperate species, the size of the voluntary reserves, human compliance with the reserves, and studies of older reserves in the region. Dive surveys of the same BRZs and reference sites included in this report should be made at least every three years to create a time-series and reveal trends in bottomfish populations at these sites. In addition, future resource monitoring should include more than two dives per site to provide larger sample sizes and greater statistical power. Several additional differences may have been statistically significant given a larger sample size.

Introduction

Dive surveys of four Bottomfish Recovery Zones (**BRZ**s) and their reference sites were undertaken following the established protocol (Eisenhardt 2001; Eisenhardt et al. 2001). Bare Island (BRZ#8) and Skipjack Island reference site were surveyed on August 26 and again on September 10. Kellett Bluff (BRZ#6) and Open Bay reference site were surveyed on August 27 and September 25. Gull Rock (BRZ#7) and Spieden Island reference site were surveyed on August 28. The second survey of these sites used the portion of Gull Rock BRZ just to the north of Flattop Island and the south side of Flattop Island as a reference site on September 11. Pile Point (BRZ#4) and Eagle Point reference site were surveyed on August 29 and September 24.

Methods and Materials

Two observers, utilizing SCUBA, completed visual belt transects. The primary diver was equipped with a depth gauge, thermometer, measuring device, and data recording slate with underwater paper and pencil. The measuring device consisted of a meter-long section of schedule 40 poly-vinyl chloride marked in 5cm intervals with one end attached to a perpendicularly mounted 30cm acrylic ruler (Paddack 1996). The secondary diver carried a 25m fiberglass tape, a data recording slate, paper and pencil. GPS coordinates were taken where the observers entered the water, usually in 10m depths. Tide Current Predictor software (Pentcheff 2000) was used to adjust depths for tide height. Any human activity in the area, especially fishing, and its intensity was recorded.

Once in the water, the observers descended and proceeded via the most direct route 2m off the bottom to a depth of 13.7m (45ft). Once there, the primary observer was tethered to the end of the fiberglass tape. Next, while staying 2m above the substrate, the primary observer began moving across the reef slope at the rate of 30 fin strokes per minute. The secondary observer remained stationary and held onto the tape reel as it unwound. While swimming the transect,

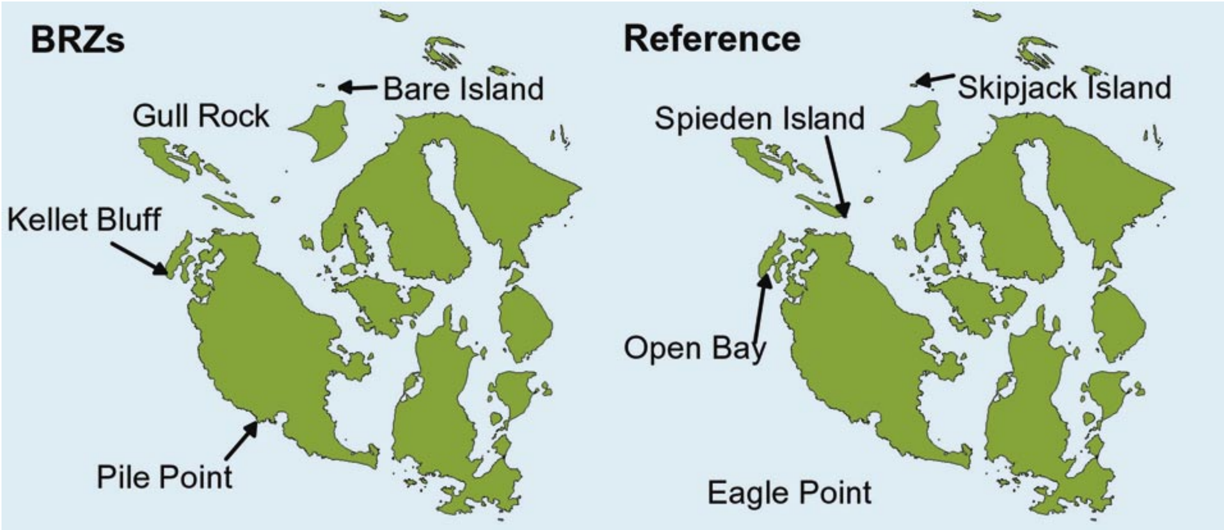


Figure 1. 2002 Survey sites. BRZs noted on left-hand map, reference sites noted on right-hand map.

the primary observer noted the depth, total length (**TL**, to nearest cm), and species for every fish encountered within a 4m x 4m x 4m cube centered on the primary observer. Total length was determined by reading off the measuring device as it was slowly placed directly against or beneath the lateral line of the fish in question, or by measuring the distance between two points on the substrate denoted by “below the tip of the lower jaw and below the posterior portion of the ventral caudal fin ray” (Martell et al. 2000). Target species included: five rockfish; copper (*Sebastes caurinus*), quillback (*Sebastes maliger*), black (*Sebastes melanops),* yellowtail (*Sebastes flavidus*), and Puget Sound (*Sebastes emphaeus*), as well as lingcod (*Ophiodon elongatus*), kelp greenling (*Hexagrammos decagrammus*), and striped surfperch (*Embiotoca lateralis*).

Through practice, the primary observer was able to change depth at a constant slope and end the 25m long transect at a pre-determined depth. For example, during the first 25m x 4m x 4m transect the primary observer would start at a depth of 13.7m (45ft) and end at a depth of 19.8m (65ft) by moving approximately parallel to shore and simultaneously increasing depth at a constant rate. During the transect, the primary observer looked left, right, up, down, and searched boulder piles and crevices. Potential bias associated with steering towards/away from fish or particular habitats was avoided by focusing only on the instantaneous 4m x 4m x 4m cube of the transect and using glances at the depth gauge coupled with sense of body position in the water to maintain a constant rate of both speed and depth change.

The secondary observer informed the primary observer when 25m of tape had been let out with three gentle tugs on the tape. Then, it was the primary observer’s turn to remain stationary while the secondary observer reeled up the tape and rejoined the primary observer. As the tape was reeled, the secondary observer passed over the transect and noted habitat characteristics to be recorded at the end of each transect. The secondary observer surveyed precisely the same 25m x 4m x 4m transect as the primary observer. Habitat data included: strike and dip of the reef slope, substrate complexity (0=sediment, 1=flat rock, 2=cobble, 3=boulder<1m, 4=boulder>1m & <3m, 5=boulder>3m), substrate percent cover (sediments, bare rock, encrusting animals, macroalgae by species), and abundance of macroinvertebrates by species.

When the secondary observer completed reeling, the observers were rejoined and flashed “OK.” Then, the primary observer began the next transect while the secondary observer remained stationary (as the tape unwound) and wrote down mentally noted data from the previous transect. In this way, waiting time was minimized for both observers. Basically, the secondary observer reeled while mentally storing habitat data, and then recorded data while stationary during the more time intensive primary fish survey.

This cycle was repeated 6 times per dive survey. From the starting point at a depth of 13.7m (45ft), the observers swam a linear distance of 25m and ended at a depth of 19.8m (65ft) for transect 1. Transect 2 consisted of a linear distance of 25m along a constant depth of 19.8m (65ft). Transects 3 and 4 were the same as transect 2, a 25m linear distance at a constant depth of 19.8m (65ft). Transect 5 began at 19.8m (65ft) and ended at 13.7m (45ft). Transect 6 began at 13.7m (45ft) and ended at 9.1m (30ft).

In summary, each dive survey consisted of six transects or 600 meters^2 of rocky reef habitat surveyed. This data collection protocol focused effort on deeper areas (below the lower limit of algal abundance) typically dominated by larger, predatory fish. The protocol provides data for analyses of fish density, which control for microhabitat driven variability in fish abundance. A variance for mean fish density per transect can be calculated for each depth stratum of each dive survey. This methodology avoids the often time consuming process of installing permanent leadline transects, and yet can still be used to monitor precisely the same (meter scale) locations on a reef year after year.

Results

Mean fish densities of lingcod (*O. elongatus*) were greater at Pile Point BRZ than Eagle Point reference site ($p = 0.026$) and Spieden-Flattop reference site than Gull Rock BRZ ($p = 0.006$). Mean densities of all other target species and site pair combinations were either not statistically significantly different, or too few fish were sighted to compute statistics (Table 1).

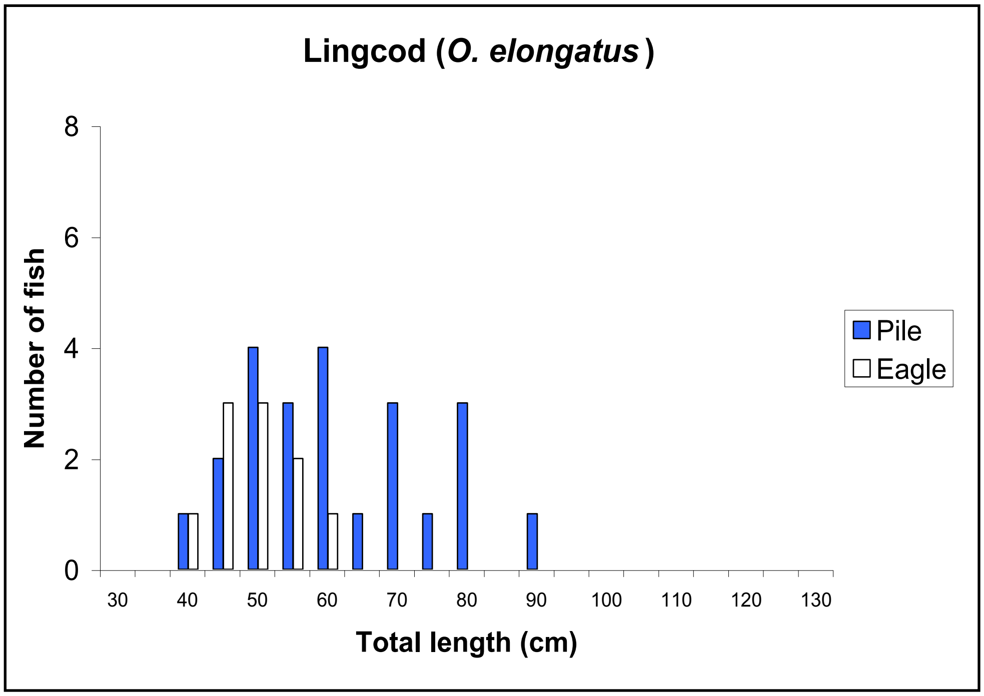
Lingcod (*O. elongatus*) sighted in the Pile Point BRZ had greater mean length compared to individuals sighted in the Eagle Point reference site ($p = 0.012$). No significant difference in mean length of lingcod was detected between Bare Island BRZ / Skipjack Island reference and Gull Rock BRZ / Spieden-Flattop Islands reference. Only one lingcod was sighted at Gull Rock, so statistics could not be calculated for the Gull Rock BRZ / Spieden-Flattop reference pair (Figure 2, Table 2). Mean length of copper rockfish (*S. caurinus*) was greater in the Pile Point BRZ ($p = 0.047$) and showed no significant difference for the other pairs (Figure 3, Table 3). Yellowtail rockfish (*S. flavidus*) were only sighted at Pile Point BRZ and Gull Rock BRZ, and therefore statistics could not be computed for any site pair (Figure 4, Table 4). There were no significant differences in mean length between any site pairs for kelp greenling (*H. decagrammus*) (Figure 5, Table 5). Striped surfperch (*E. lateralis*) exhibited a patchy distribution and were not seen in great enough numbers at both sites in any pair to make statistical comparisons (Figure 6, Table 6). Puget Sound rockfish (*S. emphaeus*) had significantly greater mean length in Pile Point BRZ ($p < 0.001$) and Kellett Bluff BRZ ($p = 0.042$) than their respective reference sites, Eagle Point and Open Bay. Puget Sound rockfish showed no significant difference in mean length at Gull Rock BRZ / Spieden-Flattop Islands reference and were not seen at Skipjack Island reference (Figure 7, Table 7). There was no significant difference in mean length of quillback rockfish (*S. maliger*) at Kellett Bluff BRZ compared to Open Bay reference, and too few quillbacks were sighted at the other sites to make statistical comparisons. A single quillback was seen at both Eagle Point reference and Bare Island BRZ, and no quillbacks were sighted at Skipjack reference, Gull Rock BRZ and Spieden-Flattop reference (Figure 8, Table 8). Black rockfish (*S. melanops*) were only seen in the Pile Point BRZ (Figure 9, Table 9). For Tables 2-9, "#DIV/0!" is listed when sample size is too small to calculate a statistic. REEF roving diver data can be accessed from their website, www.reef.org, and includes data on all species of fish and invertebrates.

Habitat analyses were conducted for each BRZ / reference site pair. In general, little difference was revealed between each BRZ and its associated reference site for the parameters of substrate percent cover (Figure 10), algal species composition (Figure 11), reef slope (Figure 12), aspect (Figure 13) and substrate complexity (Figure 14). Specifically, Flattop Island South reference site had a relatively large amount of sand substrate cover. Bare Island BRZ was the only site with cobble substrate cover. *Agarum* kelp was the predominant algal species in the area. Red algae (*Rhodophyta*) were common at Kellett Bluff BRZ and Gull Rock BRZ. Bull kelp (*Nereocyctis*) was on the transect in Pile Point BRZ, Eagle Point reference and Skipjack reference. *Ulva* was common at Open Bay reference, and *Laminaria* species were common at the Skipjack reference site. Data on reef slope were not collected at the Bare Island / Skipjack Island pair, and reef slope tended to be greater in the BRZs for the other three pairs. The Bare Island / Skipjack Island pair also had no data collected on aspect. Aspect at the other pairs did not show a trend. Substrate complexity did not appear to differ within pairs.

Table 1. Mean fish density and standard deviations for each target species by site.

FISH / 100m2	Pile (R)	Eagle (NR)	Bare (R)	Skipjack (NR)	Kellett (R)	Open (NR)	Gull-Ft (R)	Spieden-Ft (NR)
Lingcod								
mean	1.917	0.750	0.600	0.500	1.333	0.917	0.083	1.667
SD	1.311	1.055	0.699	0.789	1.073	1.084	0.289	1.614
Two-sample t test, p =	**0.026** *		p = 0.757		p = 0.354		p = **0.006** **	
Copper rockfish								
mean	2.417	1.083	2.400	0.333	1.000	1.044	1.083	0.917
SD	1.929	1.240	3.836	0.888	1.250	1.215	1.311	1.379
Two-sample t test, p =	0.059		p = 0.127		p = 0.594		p = 0.764	
Yellowtail rockfish mean	1.167	0.000	0.000	0.000	0.000	0.000	0.167	0.000
SD	2.725						0.389	
Two-sample t test, p =	ND		p = ND		p = ND		p = ND	
Kelp greenling								
mean	2.250	2.250	1.400	1.167	2.750	1.583	1.667	1.333
SD	1.055	1.288	1.265	0.718	2.301	0.900	1.155	1.435
Two-sample t test, p =	1.000		p = 0.613		p = 0.124		p = 0.538	
Striped surfperch								
mean	0.500	0.000	0.000	0.083	0.000	0.000	0.167	0.083
SD	1.168			0.289			0.577	0.289
Two-sample t test, p =	ND		p = ND		p = ND		p = 0.661	
Puget Sound rockfish mean	8.250	18.250	2.200	0.000	1.083	25.417	1.000	0.333
SD	12.152	21.141	6.286		2.610	54.846	2.594	1.155
Two-sample t test, p =	0.173		p = ND		p = 0.153		p = 0.429	
Quillback rockfish mean	0.250	0.083	0.100	0.000	0.333	0.583	0.000	0.000
SD	0.622	0.289	0.316		0.492	1.240		
Two-sample t test, p =	0.412		p = ND		p = 0.527		p = ND	
Black rockfish								
mean	2.083	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SD	6.022							
Two-sample t test, p =	ND		p = ND		p = ND		p = ND	

Mean fish density and standard deviations for each target species by site. P-values from t-tests, ND = no data as the species was not seen at one or both of the sites. N = 12 transects (4m x 25m) for all sites except Bare Island had N = 10. (R) denotes a BRZ voluntary reserve site and (NR) denotes a non-reserve or reference site.



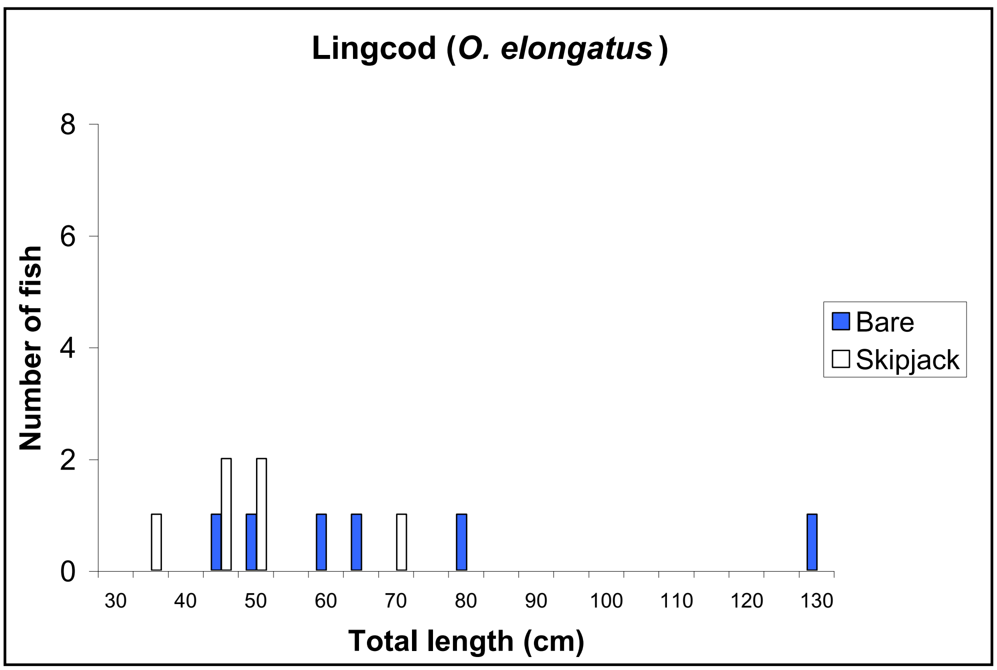


Figure 2. Length-Frequency Distribution of *O. elongatus* by BRZ/Reference Site Pairs.

Table 2. Length results for *O. elongatus* by site.

	Pile	*Eagle*	*Bare*	*Skipjack*
N	23	10	6	6
mean	61.43478	49.5	71.66667	48.83333
SD	13.43613	5.986095	31.09126	11.58303
t-test p	0.011764 *		0.12275	

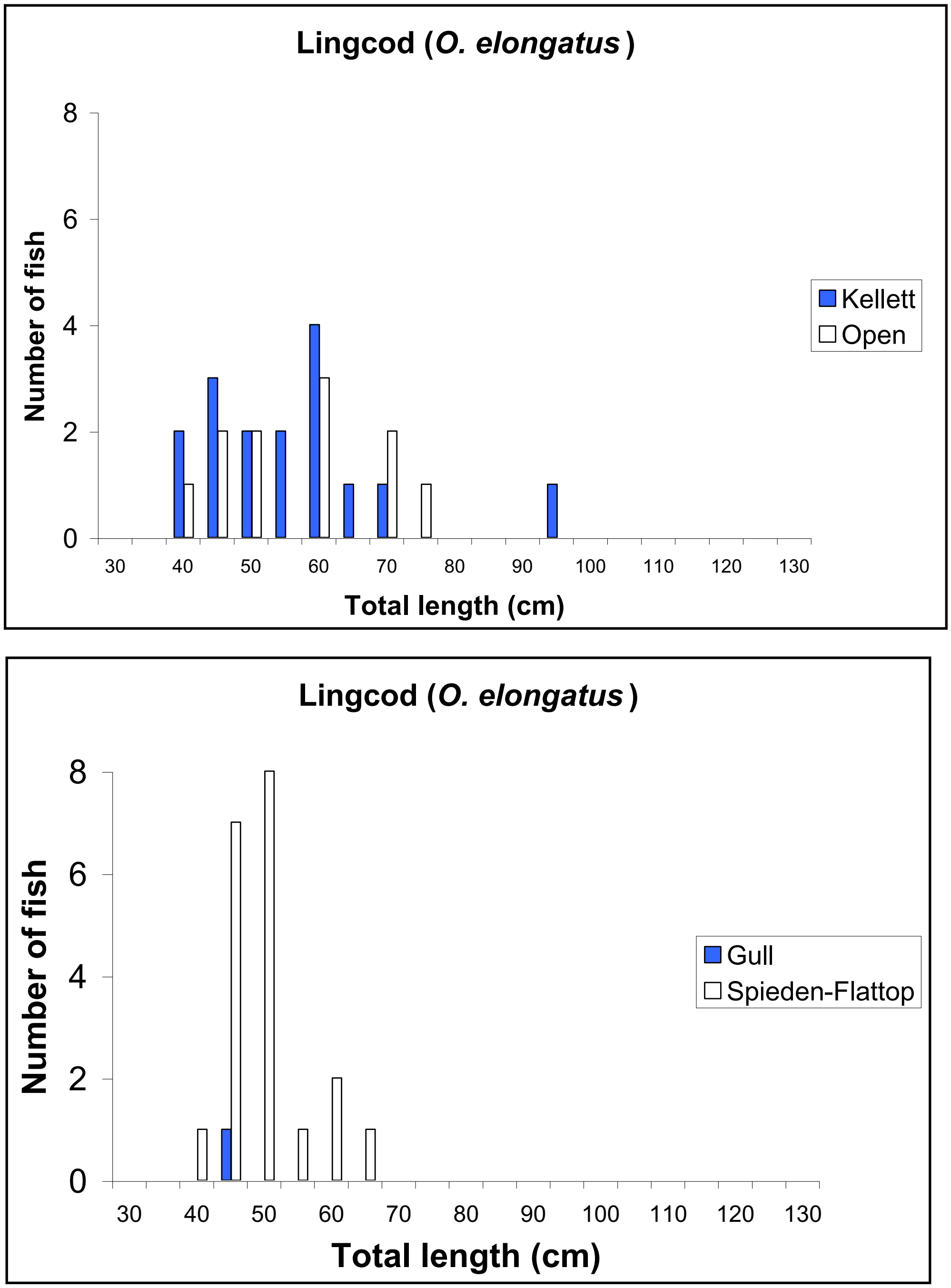


Figure 2 *(continued)* Length-Frequency Distribution of *O. elongatus* by BRZ/Reference Site Pairs.

Table 2 *(continued)* Length results for *O. elongatus* by site.

	Kellett	*Open*	*Gull*	*Spieden-Flattop*
N	16	11	1	20
mean	55.9375	56.81818	45	48.7
SD	13.68926	11.67748	#DIV/0!	6.300376
t-test p	0.863264		#DIV/0!	

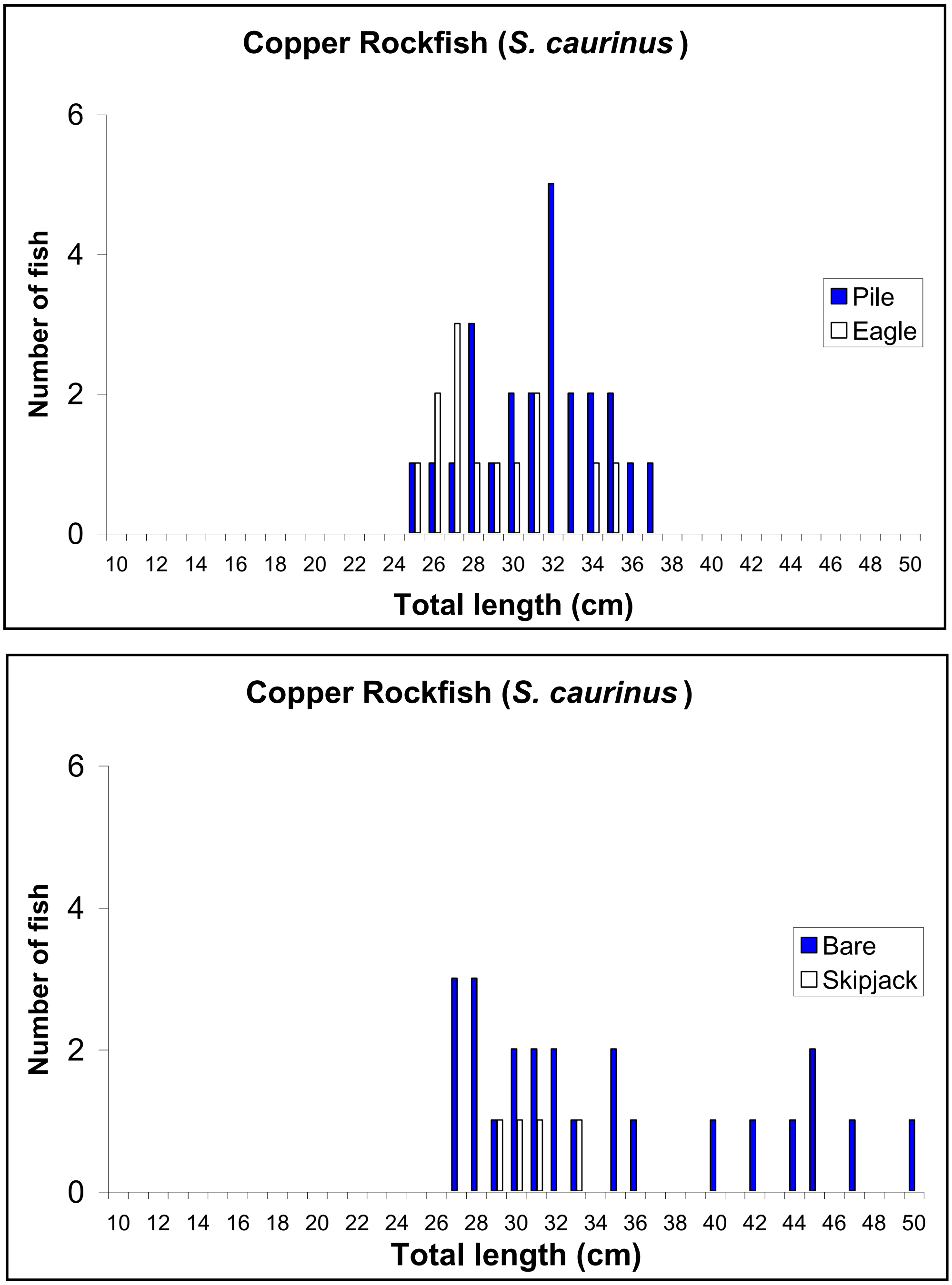
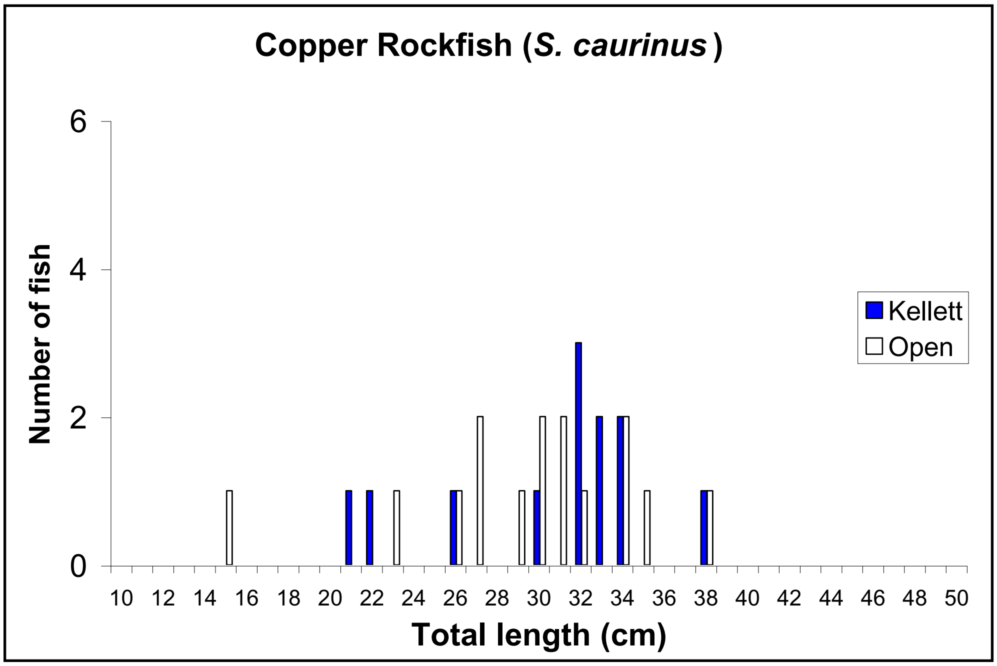


Figure 3. Length-Frequency Distribution of *S. caurinus* by BRZ/Reference Site Pairs.

Table 3. Length Results for *S. caurinus* by site.

	Pile	*Eagle*	*Bare*	*Skipjack*
N	29	13	24	4
mean	31.10345	28.92308	34.66667	30.75
SD	3.210973	3.121472	7.227163	1.707825
t-test p	0.046816 *		0.297535	



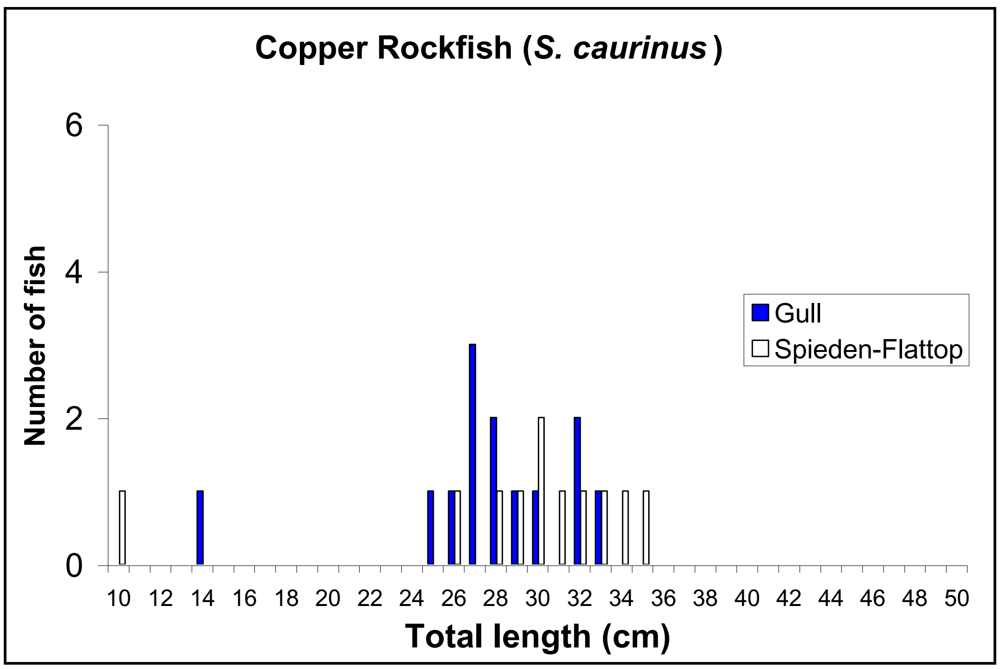
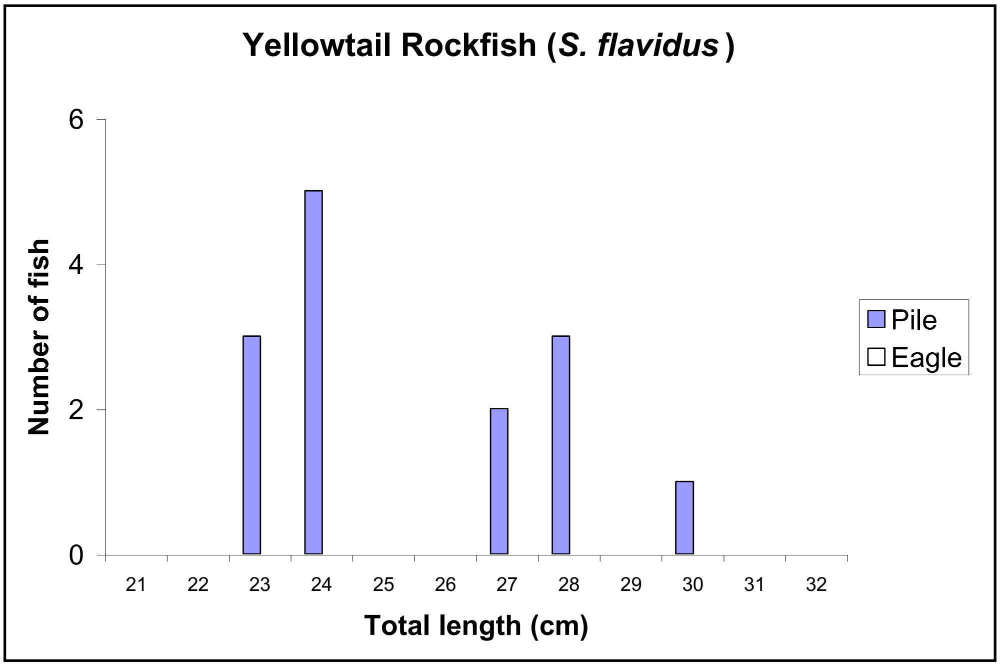


Figure 3 *(continued)* Length-Frequency Distribution of *S. caurinus* by BRZ/Reference Site Pairs.

Table 3 *(continued)* Length results for *S. caurinus* by site.

	Kellett	*Open*	*Gull*	*Spieden-Flattop*
N	12	15	13	11
mean	30.58333	29.46667	27.53846	28.90909
SD	5.071459	5.553206	4.754215	6.803742
t-test p	0.594475		0.568359	



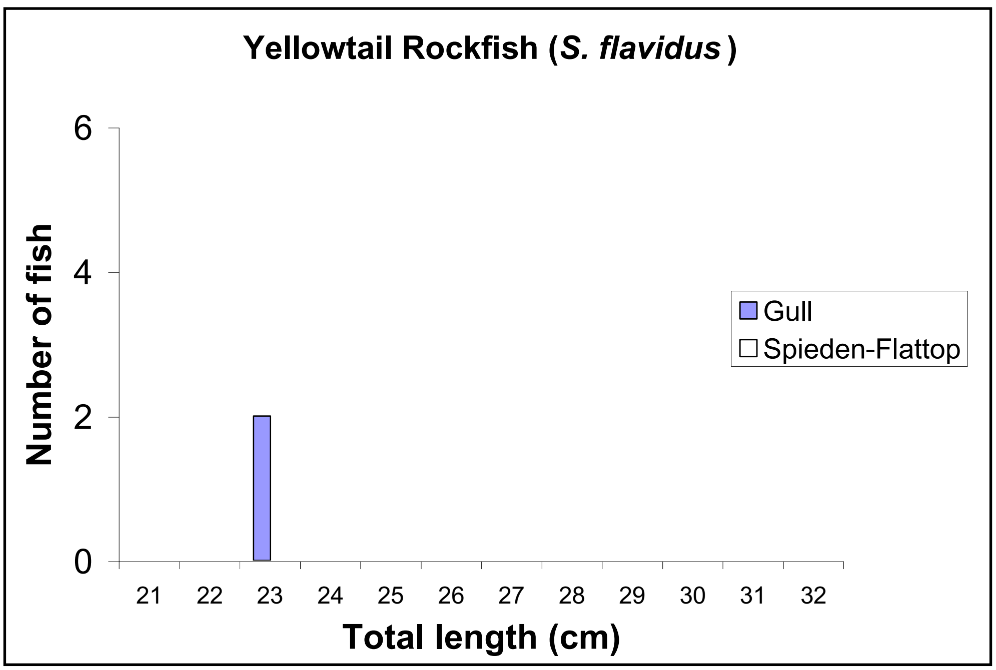
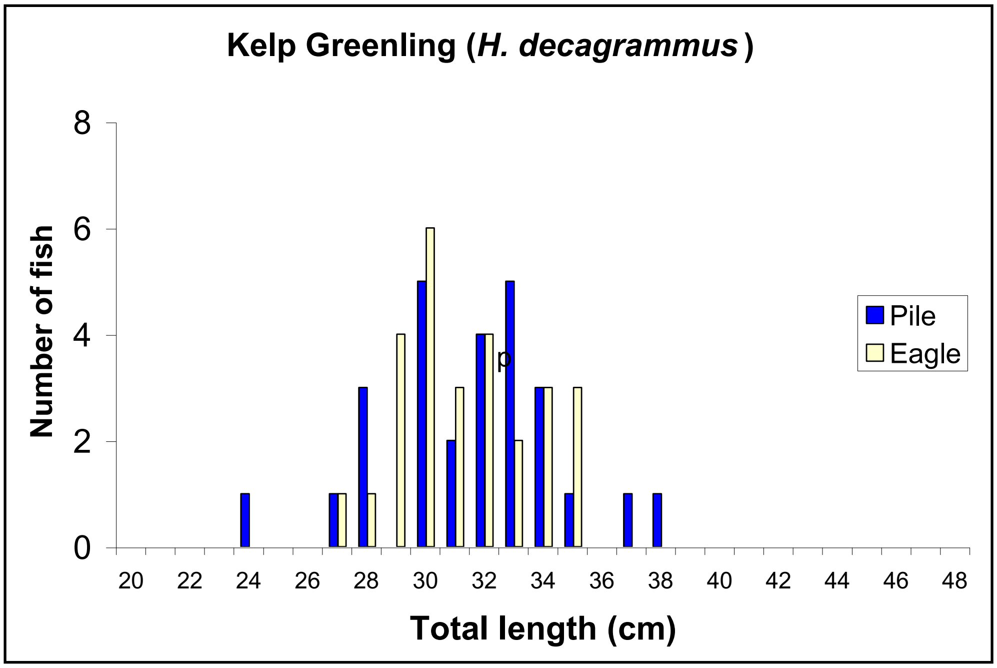


Figure 4. Length-Frequency Distribution of *S. flavidus* by BRZ/Reference Site Pairs.

Table 4. Length Results for *S. flavidus* by site.

	Pile	*Eagle*	*Gull*	*Spieden-Flattop*
N	14	0	2	0
mean	25.5	#DIV/0!	22	#DIV/0!
SD	2.377782	#DIV/0!	0	#DIV/0!
t-test p	#DIV/0!		#DIV/0!	



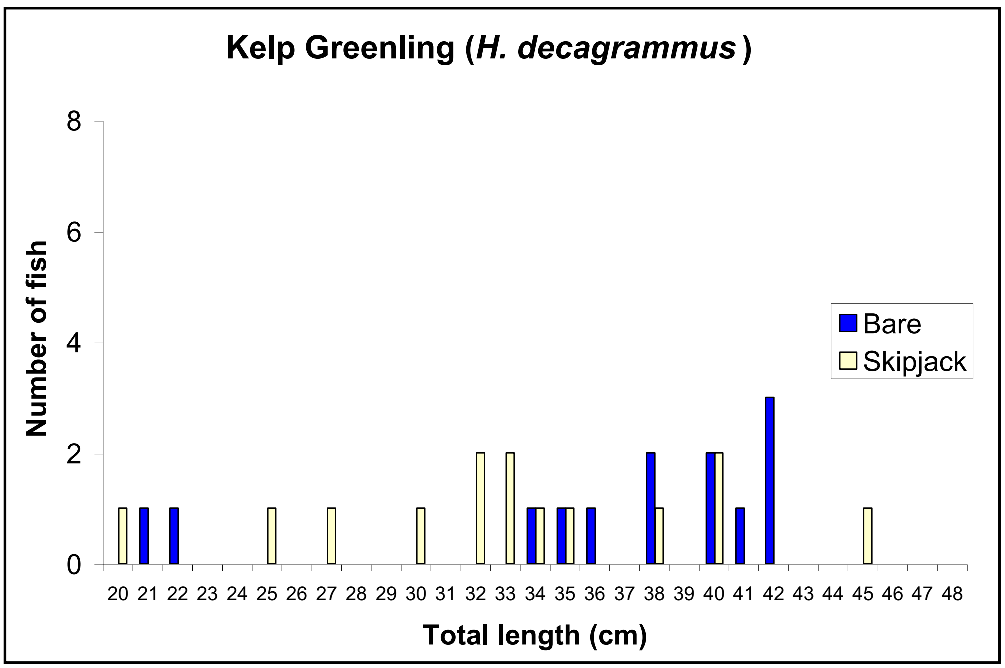
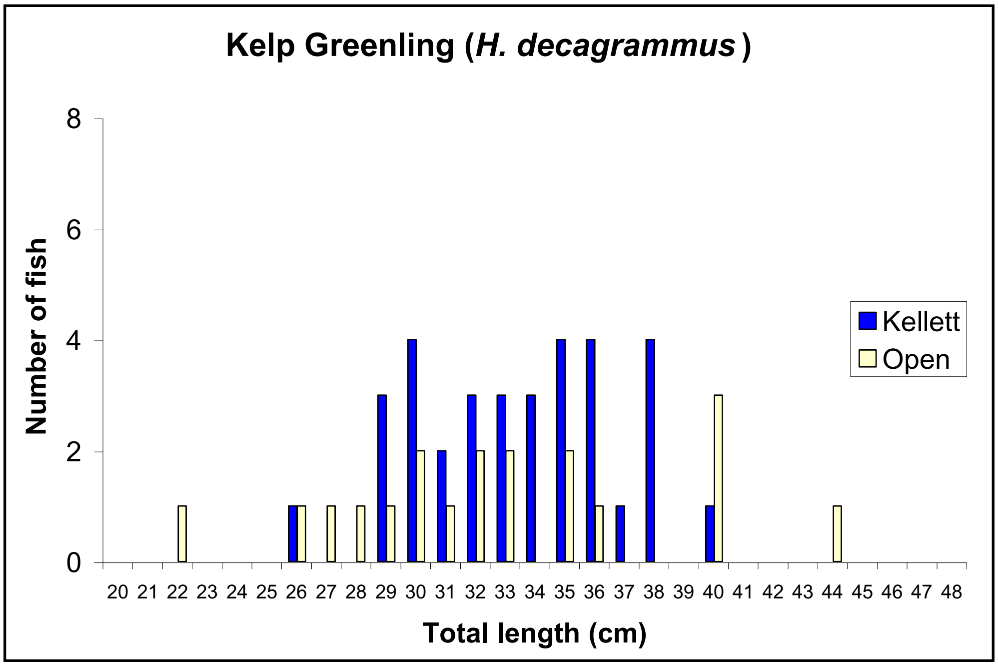


Figure 5. Length-Frequency Distribution of *H. decagrammus* by BRZ/Reference Site Pairs.

Table 5. Length Results for *H. decagrammus* by site.

	Pile	*Eagle*	*Bare*	*Skipjack*
N	27	27	14	14
mean	31.55556	31.2963	37.21429	33.14286
SD	3.042435	2.25004	7.717897	6.514565
t-test p	0.723276		0.143524	



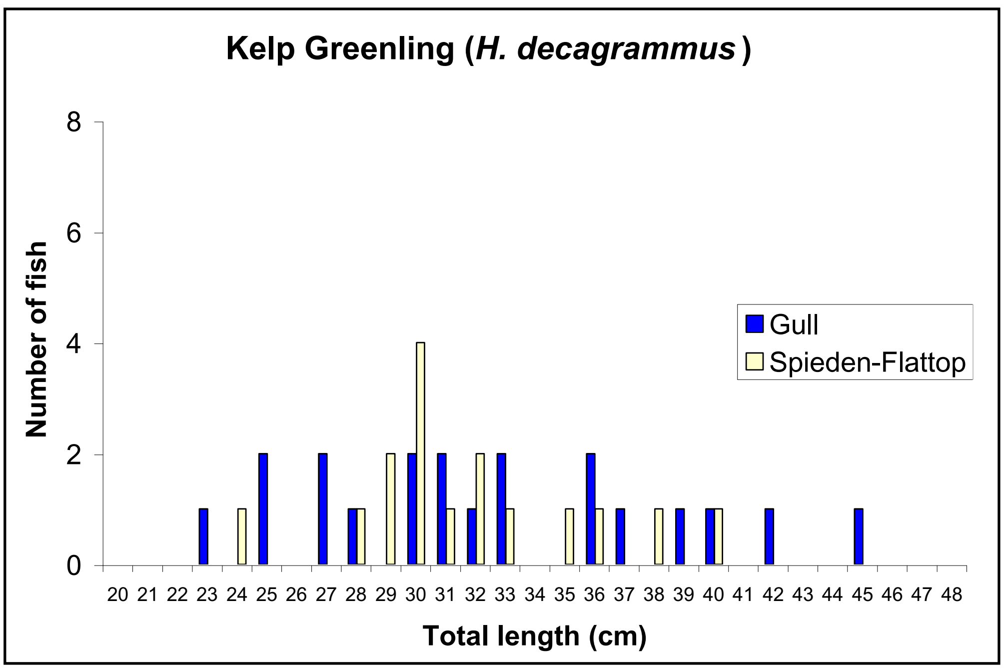


Figure 5 *(continued)* Length-Frequency Distribution of *H. decagrammus* by BRZ/Reference Site Pairs**.**

Table 5 *(continued)* Length Results for *H. decagrammus* by site.

	Kellett	*Open*	*Gull*	*Spieden-Flattop*
N	33	19	20	16
mean	33.48485	32.78947	32.5	31.6875
SD	3.336551	5.553567	6.030624	3.99531
t-test p	0.57422		0.646267	

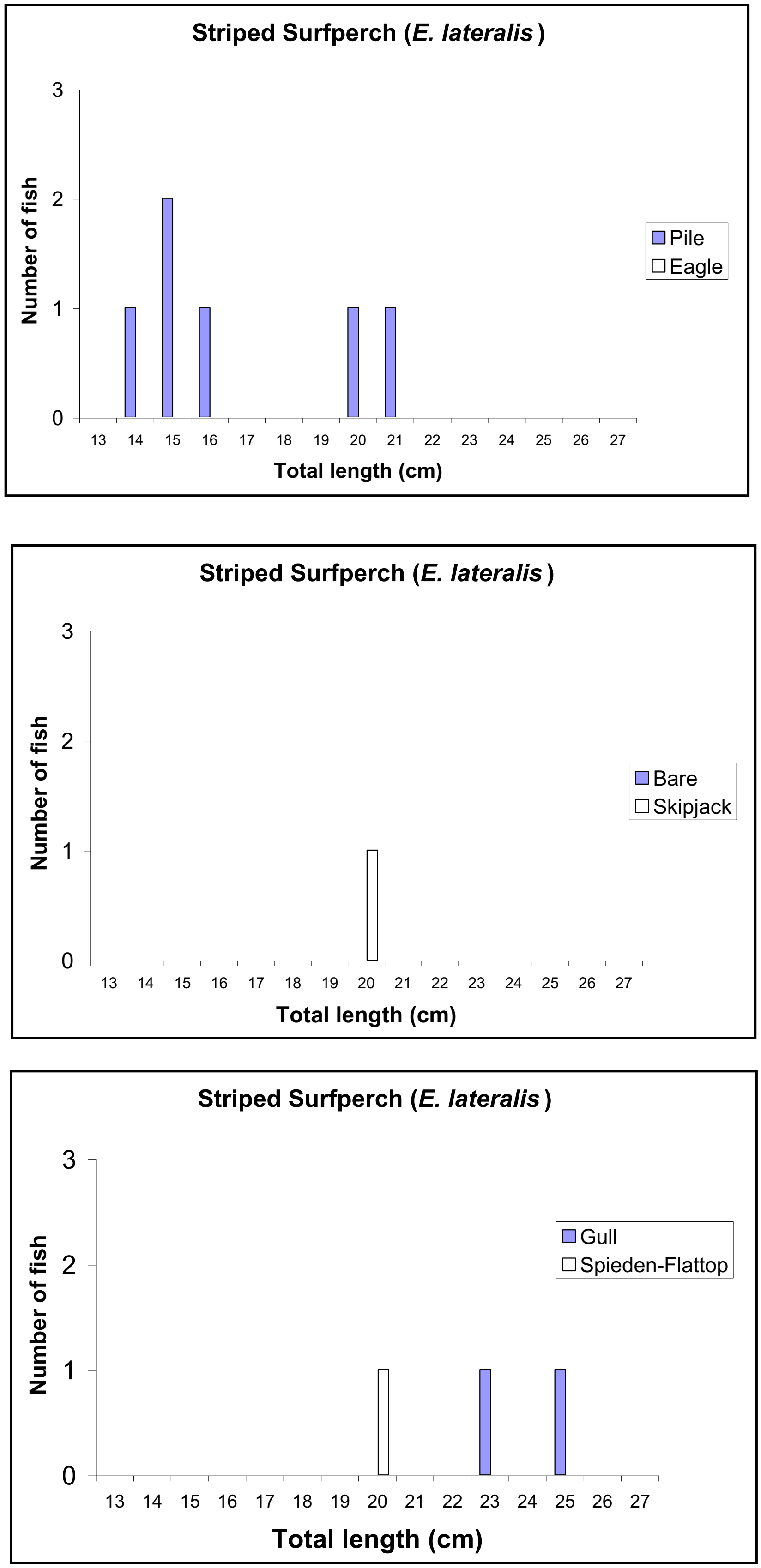
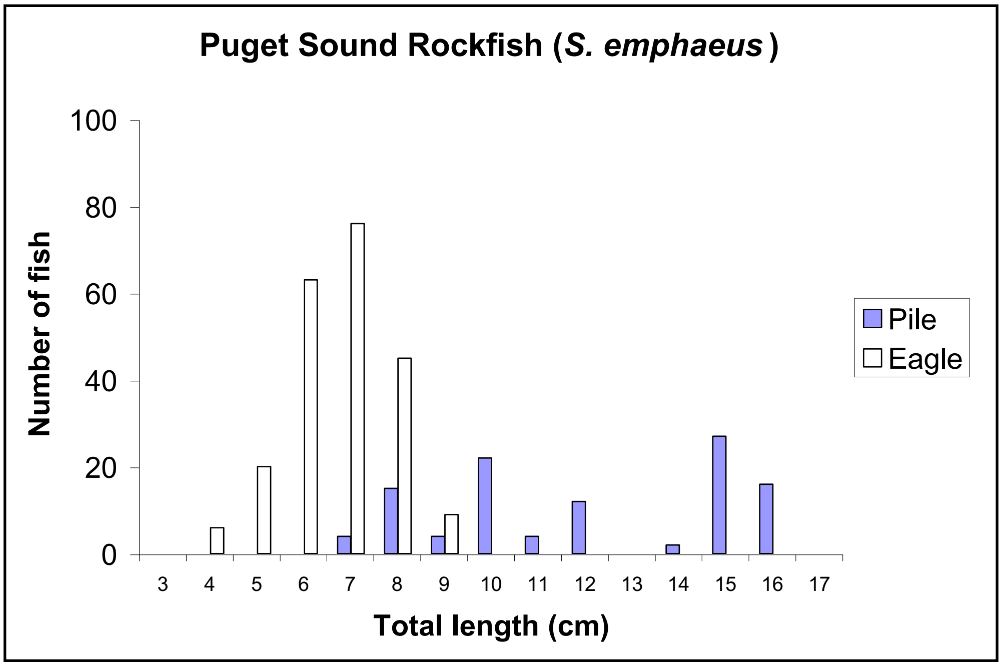


Figure 6. Length-Frequency Distribution of *E. lateralis* by BRZ/Reference Site Pairs.

Table 6. Length Results for *E. lateralis* by site.

	Pile	*Eagle*	*Bare*	*Skipjack*	*Gull*	*Spieden-Flattop*
N	6	0	0	1	2	1
mean	16.83333	#DIV/0!	#DIV/0!	20	24	20
SD	2.926887	#DIV/0!	#DIV/0!	#DIV/0!	1.414214	#DIV/0!
t-test p	#DIV/0!		#DIV/0!		#DIV/0!	



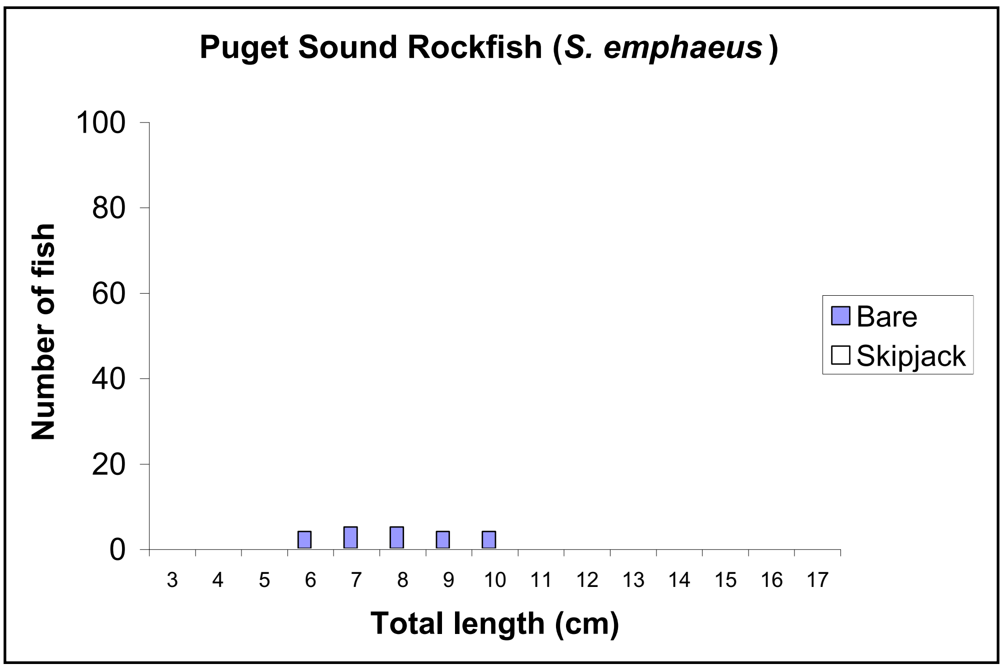
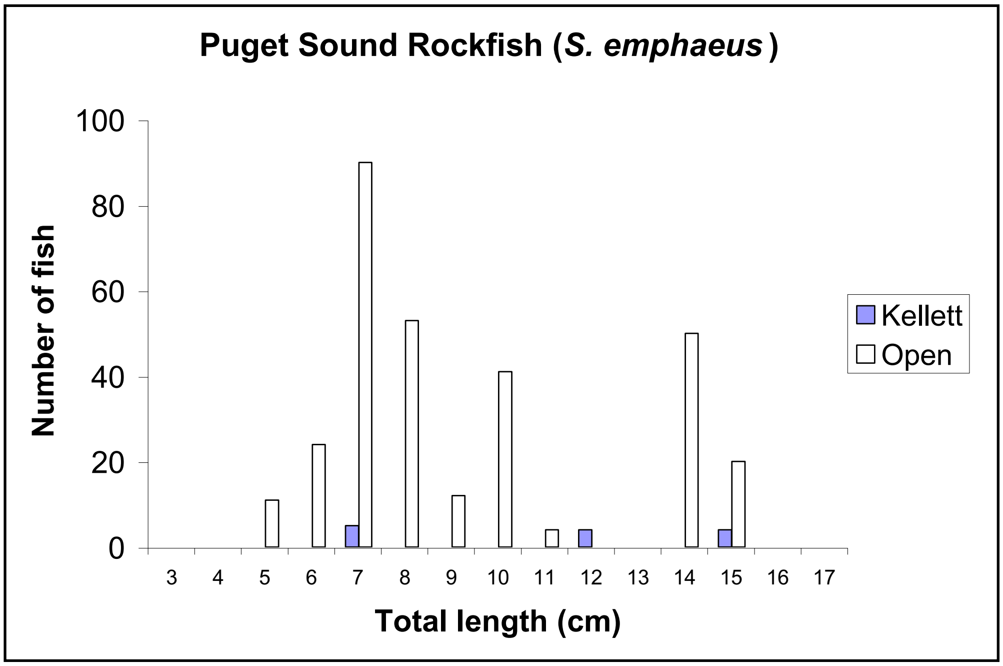


Figure 7. Length-Frequency Distribution of *S. emphaeus* by BRZ/Reference Site Pairs.

Table 7. Length Results for *S. emphaeus* by site.

	Pile	*Eagle*	*Bare*	*Skipjack*
N	106	219	22	0
mean	12.08491	6.73516	7.954545	#DIV/0!
SD	3.046053	1.097619	1.396502	#DIV/0!
t-test p	2.1E-70	***	#DIV/0!	



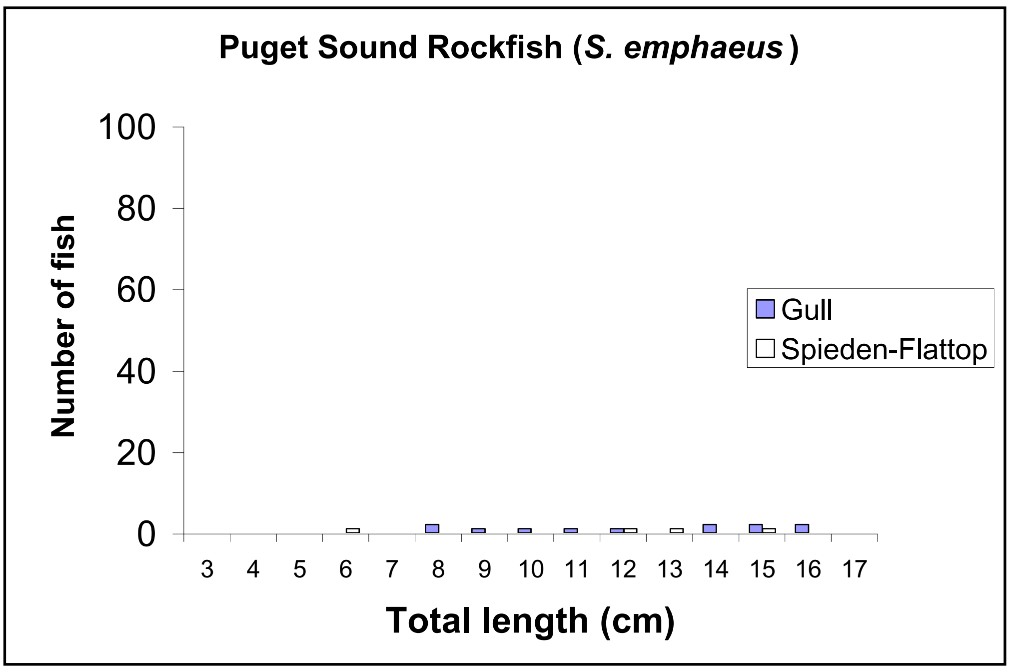


Figure 7 *(continued)* Length-Frequency Distribution of *S. emphaeus* by BRZ/Reference Site Pairs.

Table 7 *(continued)* Length Results for *S. emphaeus* by site.

	Kellett	*Open*	*Gull*	*Spieden-Flattop*
N	13	305	12	4
mean	11	9.229508	12.33333	11.5
SD	3.511885	3.043508	3.05505	3.872983
t-test p	0.042049 *		0.663526	

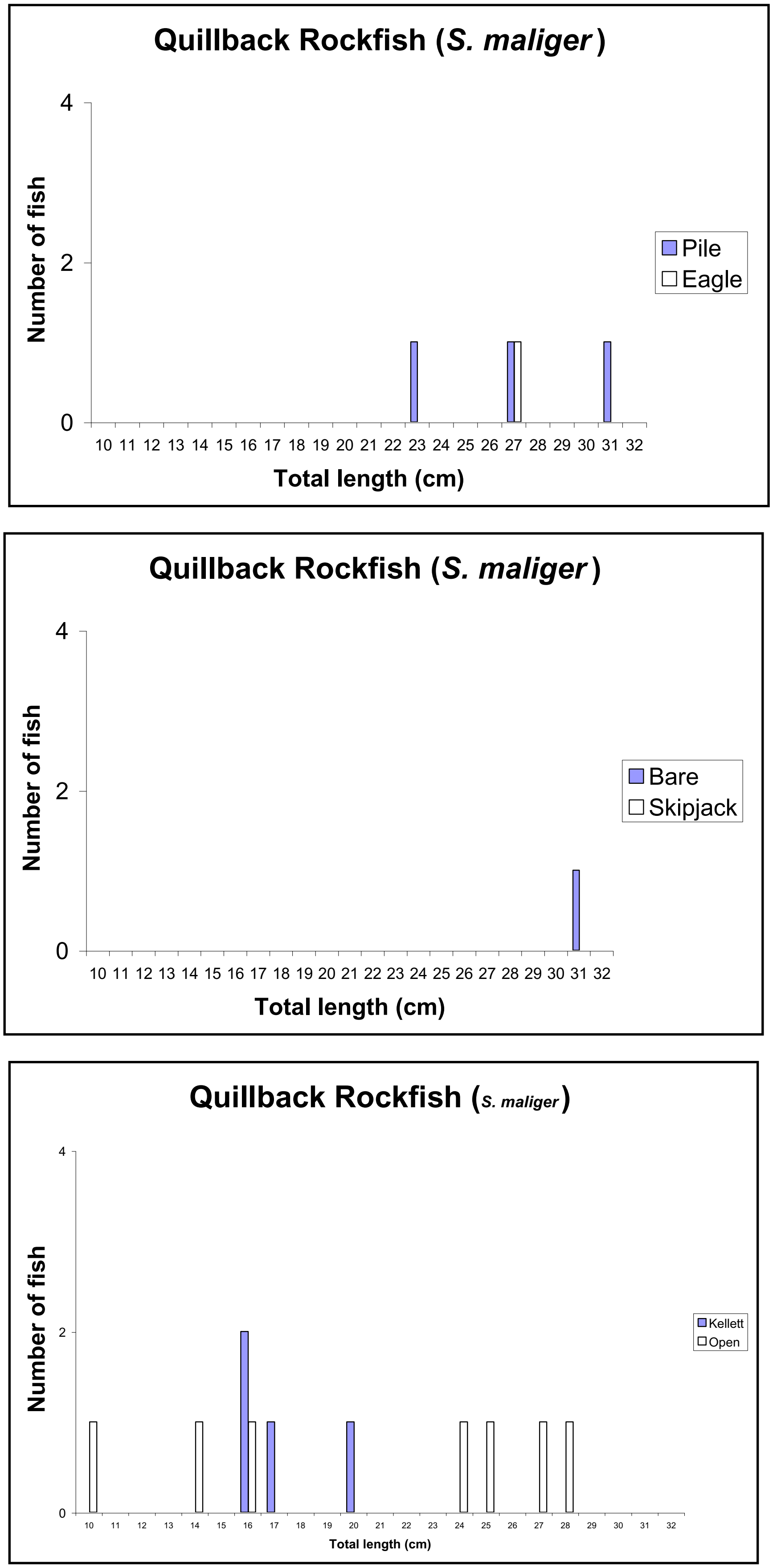


Figure 8. Length-Frequency Distribution of *S. maliger* by BRZ/Reference Site Pairs.

Table 8. Length Results for *S. maliger* by site.

	Pile	*Eagle*	*Bare*	*Skipjack*	*Kellett*	*Open*
N	3	1	1	0	4	7
mean	27	27	31	#DIV/0!	17.25	20.57143
SD	4	#DIV/0!	#DIV/0!	#DIV/0!	1.892969	7.114706
t-test p	#DIV/0!		#DIV/0!		0.393341	

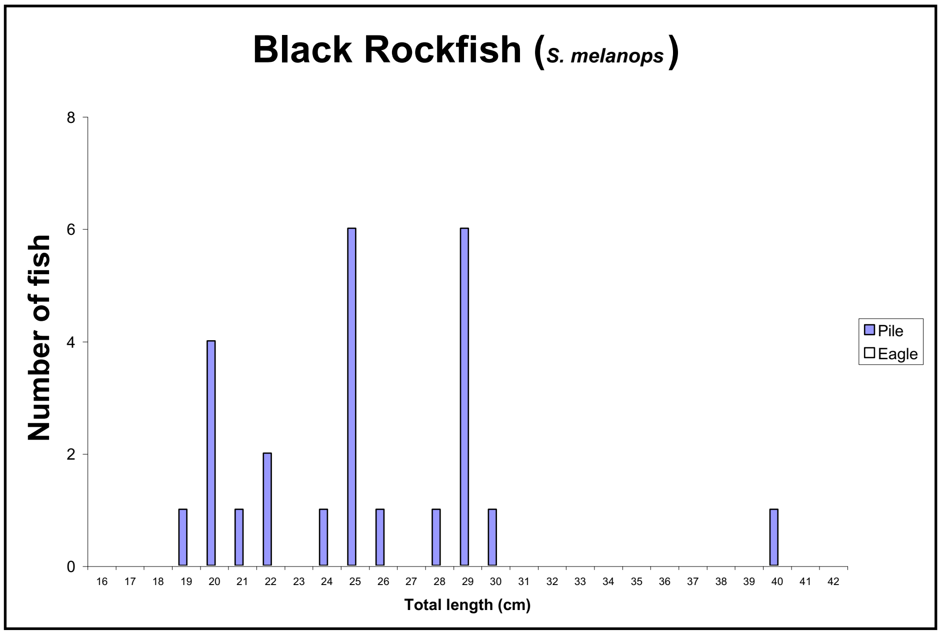


Figure 9. Length-Frequency Distribution of *S. melanops* by BRZ/Reference Site Pair**s.**

Table 9. Length Results for *S. melanops* by site.

	Pile	*Eagle*
N	25	0
mean	25.44	#DIV/0!
SD	4.664404	#DIV/0!
t-test p	#DIV/0!	

Table 10. Physical data collected in sampling dives.

SITE	DATE	Subtidal Visibiity (m)	Distance Surveyed (m)	Area Surveyed (ha)	Bottom Temp (deg C)	Maximum Depth (ft)	Duration (min)	Current (knots)	Start Time
Bare	26-Aug-02	9.1	100	0.04	11.4	60	35	0	1423
Skipjack	26-Aug-02	4.6	150	0.06	10.4	56	34	2	1606
Open	27-Aug-02	6.9	150	0.06	10.2	68	35	0	1326
Kellett	27-Aug-02	7.6	150	0.06	11.1	69	37	0	1457
Gull	28-Aug-02	12.2	150	0.06	10.6	66	35	0	0831
Spieden	28-Aug-02	10.7	150	0.06	10.1	66	36	0	1006
Pile	29-Aug-02	9.1	150	0.06	10.3	66	35	0	1038
Eagle	29-Aug-02	9.1	150	0.06	10.1	71	40	0	0922
Bare	10-Sep-02	9.0	150	0.06	9.8	61	33	2	1506
Skipjack	10-Sep-02	8.5	150	0.06	10.1	61	35	0	1630
Flattop South	11-Sep-02	7.9	150	0.06	10	70	37	0	1245
Flattop North	11-Sep-02	6.4	150	0.06	10.1	71	34	0	1410
Eagle	24-Sep-02	13.1	150	0.06	9.4	70	35	0	1329
Pile	24-Sep-02	13.1	150	0.06	9.3	72	38	0	1500
Open	25-Sep-02	11.0	150	0.06	9.5	73	42	0	1258
Kellett	25-Sep-02	10.4	150	0.06	10.2	73	45	0	1452

Table 11. Start points and direction swum for each dive survey.

SITE	DATE	Start point (N. Lat)	Start point (W. Long)	Direction swam from GPS point
Bare	26-Aug-02	48’43.812”	123’01.361”	south
Skipjack	26-Aug-02	48’43.883”	123’02.342”	east
Open	27-Aug-02	48’35.214”	123’11.635”	north
Kellett	27-Aug-02	48’35.475”	123’12.198”	south
Gull	28-Aug-02	48’39.035”	123’05.394”	east
Spieden	28-Aug-02	48’37.958”	123’06.469”	east
Pile Point	29-Aug-02	48’28.875”	123’05.621”	north
Eagle Point	29-Aug-02	48’27.494”	123’02.285”	north
Bare	10-Sep-02	48’44.170”	123’01.228”	southwest
Skipjack	10-Sep-02	NE side, east of haulout		southeast
Flattop South	11-Sep-02	48’39.028”	123’04.953”	west
Flattop North	11-Sep-02	48’39.203”	123’05.083”	west
Eagle Point	24-Sep-02	48’27.486”	123’02.230”	north
Pile Point	24-Sep-02	48’28.989”	123’05.751”	north
Open	25-Sep-02	48’35.148”	123’11.847”	east
Kellett	25-Sep-02	48’35.659”	123’12.099”	north

Table 12. Weather and fishing activity observed before and after each dive.

SITE	DATE	Weather	Fishing before	Fishing after
Bare	26-Aug-02	sun, calm	0	One boat in area briefly. Possibly bottomfish jigging
Skipjack	26-Aug-02	sun, calm	0	0
Open	27-Aug-02	sun, calm	0	0
Kellett	27-Aug-02	sun, calm	0	0
Gull	28-Aug-02	sun, calm	0	0
Spieden	28-Aug-02	sun, calm	0	1 boat, 2 rods jigging in 100-150 ft of water
Pile Point	29-Aug-02	p. cloudy, calm	0	L-pod (resident orcas)
Eagle Point	29-Aug-02	p. cloudy, surge	3 salmon trollers	4 salmon trollers
Bare	10-Sep-02	p. cloudy, calm	0	0
Skipjack	10-Sep-02	p. cloudy, calm	0	0
Flattop South	11-Sep-02	sun, 5-10 NE	0	0
Flattop North	11-Sep-02	sun, 5-10 NE	0	0
Eagle Point	24-Sep-02	sun, calm	0	0
Pile Point	24-Sep-02	sun, calm	0	0
Open	25-Sep-02	sun, calm	0	0
Kellett	25-Sep-02	sun, calm	0	0

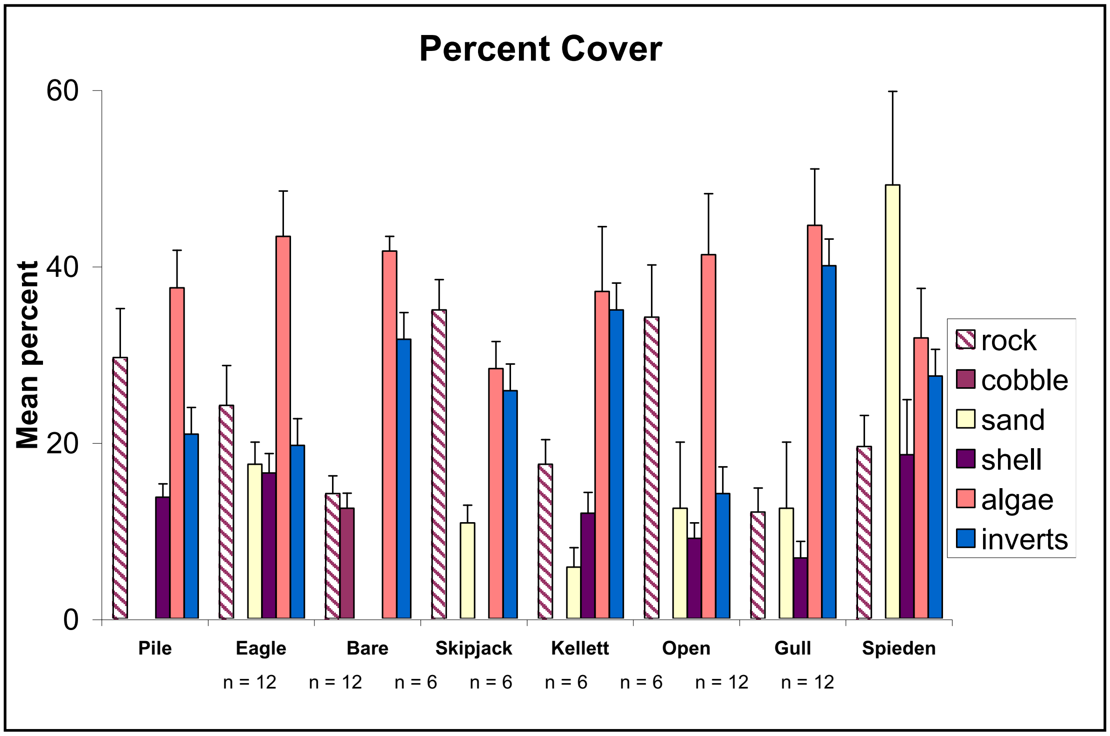


Figure 10. Mean percent cover for each study site.

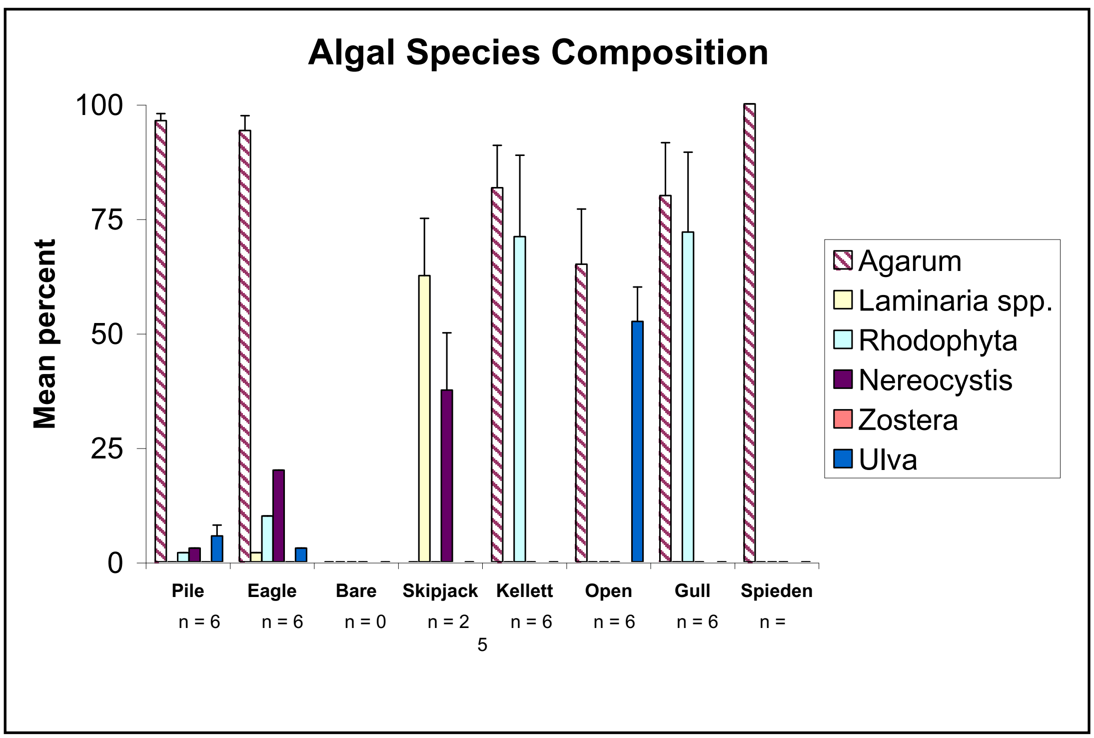


Figure 11. Algal species composition for each study site.

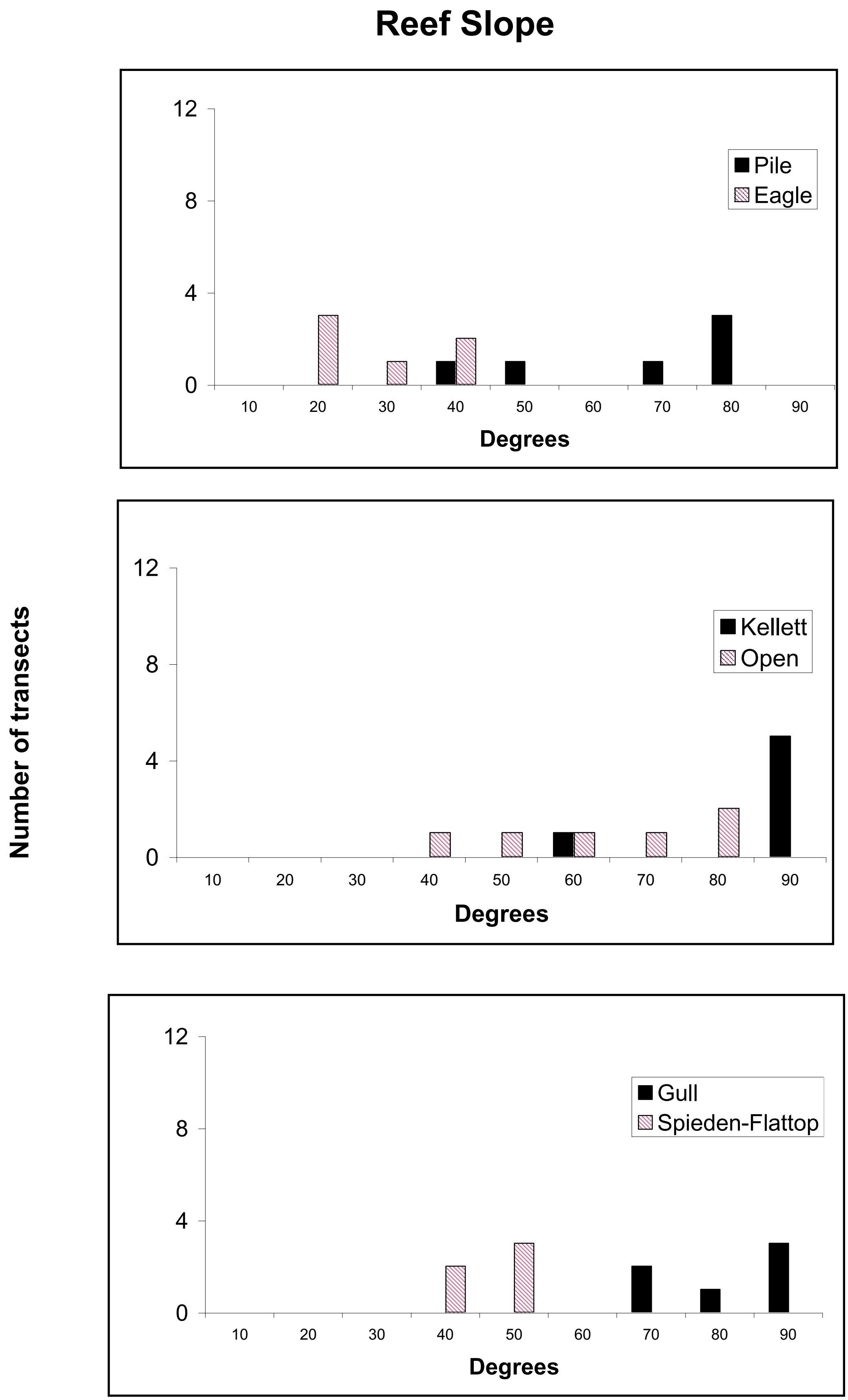


Figure 12. Frequency distribution of reef slope for each BRZ / reference site pair.

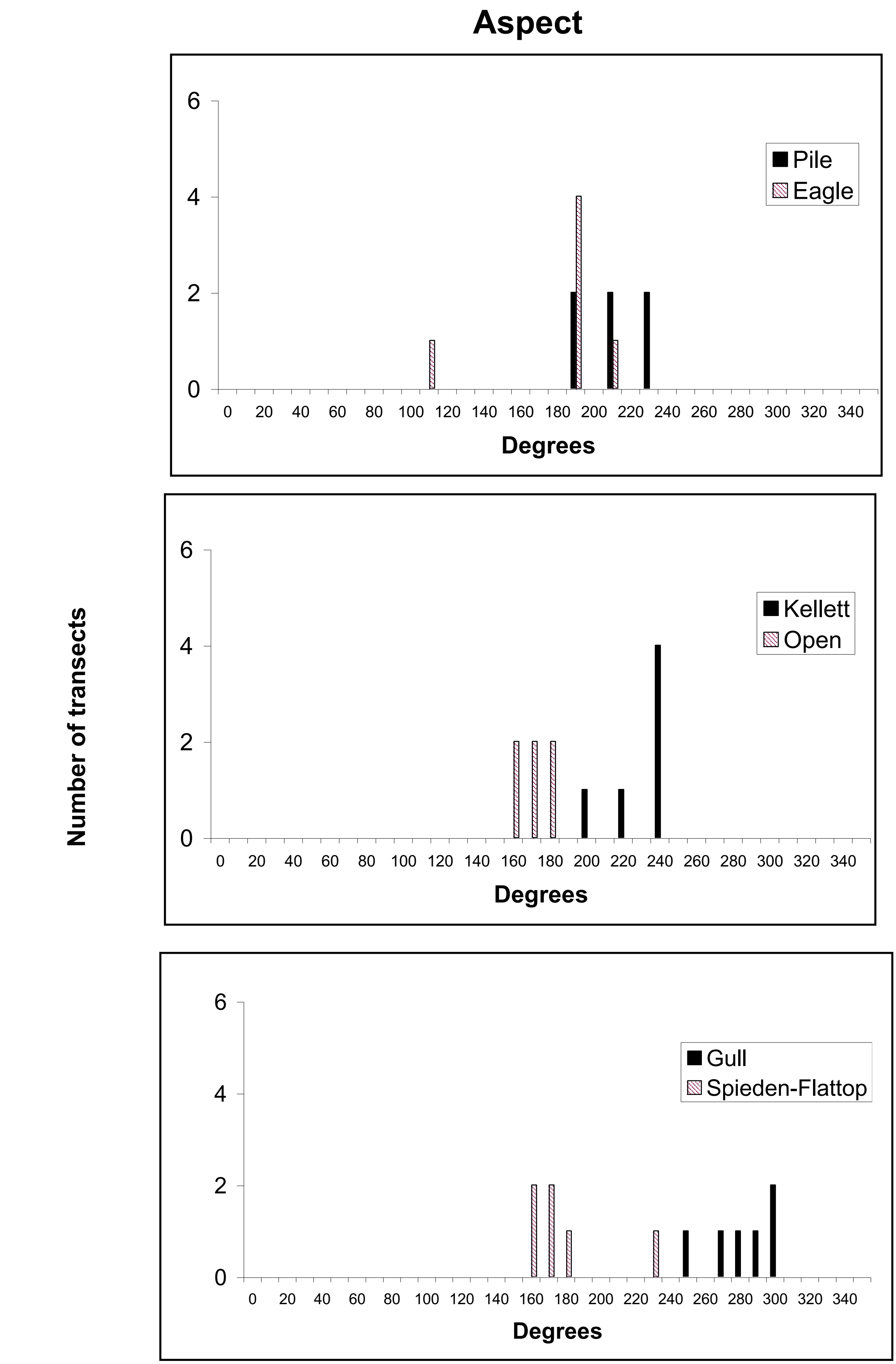


Figure 13. Aspect frequency distributions for each BRZ / reference site pair.

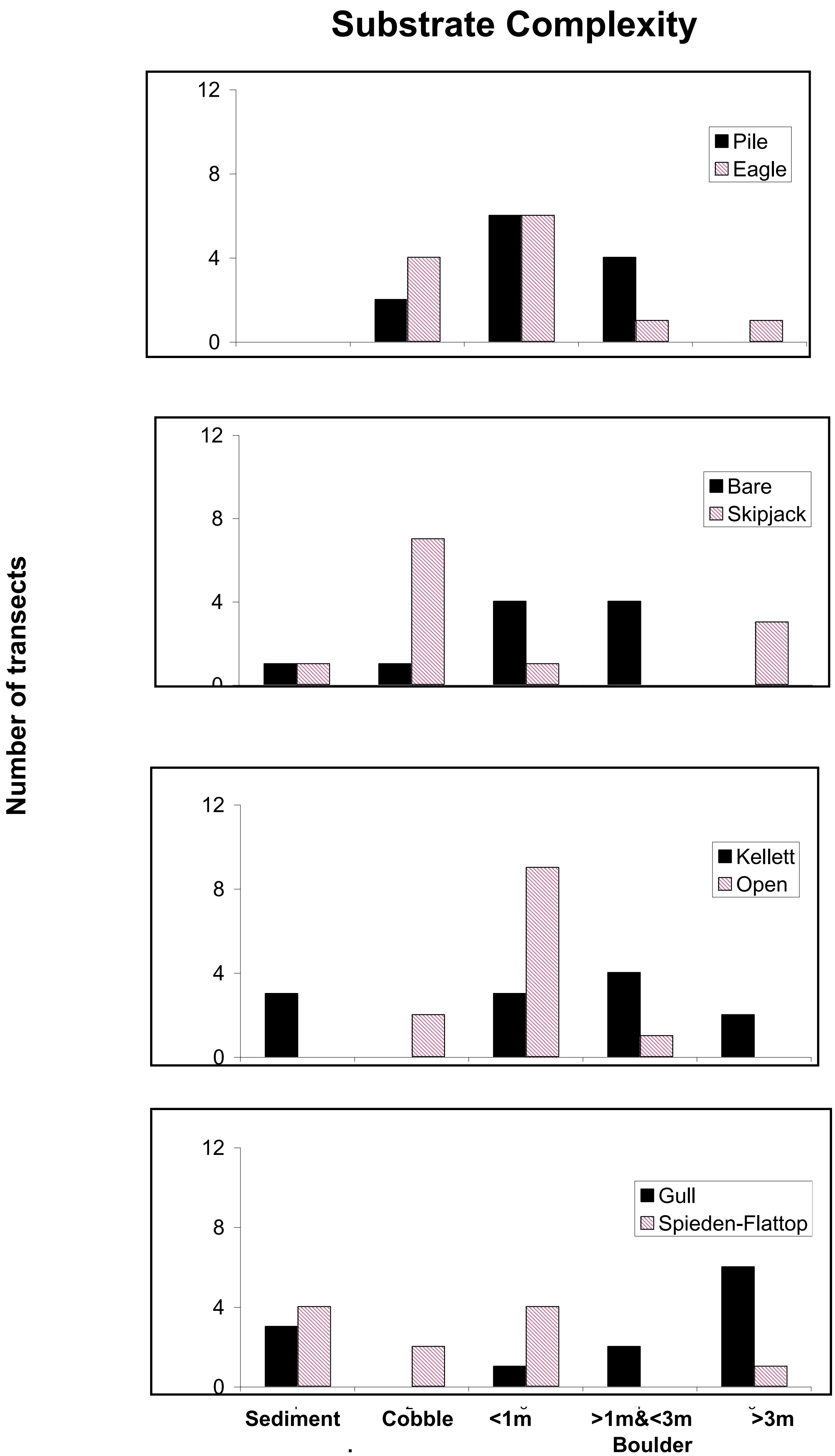


Figure 14. Substrate complexity frequency distributions for each BRZ / reference site pair.

Discussion

Most of the statistically significant differences between site pairs occurred between the Pile Point BRZ and the Eagle Point reference site. These differences may be related. Lingcod were significantly more abundant and larger at Pile Point, and given their ecological role of apex predator, lingcod may be structuring the demographics of some other species through predation. For example, it appears that lingcod prefer smaller Puget Sound rockfish as prey, given the coupling of larger mean length with fewer fish per area for Puget Sound rockfish at the site with larger and more abundant lingcod.

The same pattern of more abundant lingcod and larger and fewer Puget Sound rockfish is also evident in the Kellett Bluff BRZ / Open Bay reference site pair. However, for this site pair the pattern is without full statistical significance due to high variance associated with Puget Sound rockfish densities and a smaller difference in mean density of lingcod. An alternate explanation for this pattern could be that adult Puget Sound rockfish prefer one site to the other, perhaps due to presence and absence of favorable currents to deliver their planktonic prey. This may be case for the Kellett Bluff BRZ / Open Bay reference site pair, as tidal currents off Kellett Bluff are particularly strong and Open Bay is relatively removed from tidal current influence. However, Pile Point and Eagle Point have very similar tidal current environments making adult Puget Sound rockfish site preference due to current unlikely.

The second greatest densities of lingcod were found at the Spieden-Flattop Islands reference site, however evidence of higher levels of predation there was not clear. Puget Sound rockfish were three times less abundant in the Spieden-Flattop Islands reference site, but this was not a statistically significant result. However, Puget Sound rockfish in both the reference and Gull Rock BRZ were scarce compared to other sites, so a predation effect could be masked by low initial population densities of this species at both sites.

There appeared to be some evidence of a similar pattern of predation for copper rockfish. For the Pile Point BRZ / Eagle Point reference site pair, the significantly larger and more abundant lingcod corresponded with greater mean length of copper rockfish—again possibly indicating lingcod preference for smaller copper rockfish prey. The same pattern (although with reserve and non-reserve sites switching roles) was evident for Gull Rock BRZ and Spieden-Flattop Islands reference sites. However, in this case the difference in copper rockfish mean length was not statistically significant.

Black rockfish were only sighted at Pile Point BRZ. It should be noted that most of these individuals were smaller than black rockfish sighted at other sites in the region, indicating relatively recent recruitment at Pile Point BRZ. This is positive information for potential recovery of this regionally declined species. The small black rockfish population at Pile Point should not be fished, but rather allowed to grow and potentially repopulate the region.

Substantial volunteer data collection effort was used in 2002. The results were mixed. For the most part, roving diver surveys went well and data collected was of high quality. Habitat data collection did not go as well. As was expected, volunteers took some time to reach proficiency at recording all habitat parameters. As a result, many habitat parameters were not collected on several transects. In addition, use of volunteers required using two different habitat observers over the course of the dive surveys, which introduced multiple observer bias and increased the number of dives with an unproficient habitat observer while they learned the protocol.

Future Research

The most critical need for this program is continued resource monitoring to provide data for analyses of temporal trends. Comparing the effect of these voluntary “no-take” zones spatially, as was done in this report, is a good first step when available data is limited to a one-year snap shot. However, definitive proof of the effect of these reserves will require analyses of temporal trends and comparison of these trends between BRZ and reference sites. Now that baseline data for the majority of these sites has been collected, temporal resource monitoring can begin with the next round of dive surveys.

Dive surveys of the same BRZs and reference sites included in this report should be made on three year intervals to create a time-series with enough temporal resolution to reveal trends and predict recovery times of bottomfish populations in the region. Positive reserve effects may take a decade or longer to become detectable given the population growth potential of these temperate species, the size of the voluntary reserves, human compliance with the reserves, and studies of older reserves in the region. However, sampling several times within a decade time interval will provide precise rates of recovery for different species with different ages to reproduction and longevity.

In the future, additional funding for paid research assistants throughout the duration of surveying is recommended. Volunteers can collect useful data, but the training time to data collection proficiency results in more surveys with incomplete habitat data as the volunteer learns the protocol. Having the same volunteer for the duration of the dive surveys would minimize the problem. However, volunteers are not normally available for all survey dates. Support for a paid research assistant would eliminate the possibility to train multiple secondary observers and improve quality of the habitat data generated by the resource monitoring.

Finally, more dive surveys need to be done at each site over the course of sampling site to provide larger sample sizes and greater statistical power. Several differences may have been statistically significant with larger sample sizes. Limited funding provided for only two surveys at each site. Previous work showed that four dive surveys per site provided an adequate sample size (Eisenhardt 2001). In the future, a sample size of four dives should be used for surveying BRZs. If funding is again limiting, then the number of sites surveyed per year should be reduced.

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